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Technical advances improved outcome in patients undergoing surgery of the ascending aorta and/or aortic arch: ten years experience

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Abstract

Background: Several technical advances in thoracic aortic surgery, such as the use of antegrade cerebral perfusion, avoidance of cross-clamping and the application of glue, have beneficially influenced postoperative outcome. The aim of the present study was to analyse the impact of these developments on outcome of patients undergoing surgery of the thoracic aorta. **Methods and results:** Between January 1996 and December 2005, 835 patients (37.6%) out of 2215 aortic patients underwent surgery on the thoracic ascending aorta or the aortic arch at our institution. All in-hospital data were assessed. Two hundred and forty-one patients (28.8%) suffered from acute type A dissection (AADA). Overall aortic caseload increased from 41 patients in 1996 to 141 in 2005 (+339%). The increase was more pronounced for thoracic aortic aneurysms (TAA) (+367.9%), than for acute type A aortic dissections (+276.9%). Especially in TAA, combined procedures increased and the amount of patients with impaired left ventricular function (EF <50%) raised up from 14% in 1996 to 24% in 2005. Average age remained stable. Logistic regression curve revealed a significant decrease in mortality (AADA) and in the overall incidence of neurological deficits. **Conclusions:** Technical advances in the field of thoracic aortic surgery lead to a decrease of mortality and morbidity, especially in the incidence of adverse neurological events, in a large collective of patients. Long-term outcome and quality of life are better, since antegrade cerebral perfusion has been introduced.

Keywords: Thoracic aorta; Aneurysm; Dissection; Outcome; Cerebral perfusion

1. Introduction

Surgery on the thoracic aorta for thoracic aortic aneurysms (TAA) and for acute type A aortic dissections (AADAs) is still associated with considerable mortality and morbidity, especially in patients with AADA [1—4]. In the last decade, innovative surgical techniques for cerebral and myocardial protection and improvements in anaesthesia and critical care have enhanced patient survival. Several technical advances in aortic surgery have been made; the avoidance of cross-clamping the aorta reduces manipulations of the diseased aorta and therefore the incidence of embolization. Cerebral protection during deep hypothermic arrest (DHCA) has considerably improved, since antegrade cerebral perfusion has been introduced in clinical routine [5—7]. The use of glue, sometimes discussed controversially [20,21] due to glue related necrotic alterations of the aortic wall, allows on the other hand to adapt the three layers of the diseased aorta and to reduce flow in the false lumen.

Several studies have demonstrated that the mentioned refinements of surgical techniques, result in a decreased mortality and morbidity in this high-risk collective of patients. The introduction of antegrade cerebral perfusion (ACP) in clinical routine is especially associated with reduced mortality and adverse neurological outcome [5—7]. Our group has furthermore shown that the introduction of ACP beneficially affects long-term quality of life in patients undergoing thoracic aortic surgery under DHCA [5].

Based on these improvements, the use of deep hypothermic circulatory arrest has become more liberal than a few years ago and more complex aortic pathologies can be treated successfully by open repair. With the introduction of cerebral protection during circulatory arrest with cold, antegrade cerebral perfusion, deep hypothermic circulatory arrest is being abandoned for moderate hypothermia during the circulatory arrest [8].

The aim of the present study was to analyse the impact of these developments on outcome of patients undergoing surgery of the thoracic aorta in the last decade.

2. Patients and methods

Between January 1996 and December 2005 a total of 835 consecutive patients (37.6%), out of 2215 aortic patients underwent surgery on the ascending aorta or the aortic arch

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at our institution. All in-hospital data were assessed. Median age was 60 years, and 611 patients (73.2%) were male. A total of 146 patients (17.5%) had undergone previous cardiac or aortic operations. Indication for surgical interventions was AADA in 241 patients (28.8%) and aortic aneurysms in 594 patients (71.3%). A total of 271 patients (32.5%) were classified with annuloaortic ectasia. Emergency surgery was performed in 265 patients (31.6%), 94 patients (11.2%) had an acute pericardial tamponade and were hemodynamically compromised. Of the 241 patients with AADA 83 patients (34.4%) presented with malperfusion syndrome (MPS), one third with neurological MPS and one third with MPS of the extremities.

History of arterial hypertension was the most common general preoperative risk factor (58.7%), followed by a history of smoking (34.8%) and diabetes mellitus (8.4%). Patients' characteristics are displayed in Table 1.

2.1. Operative technique

All patients received standard general anaesthesia. All operations were performed through a median sternotomy. For ascending aortic repair either a Bentall procedure or a supracoronary replacement of the ascending aorta was performed. In 227 patients (27.2%) ascending aorta or aortic arch replacement was combined with coronary artery bypass grafting (CABG) and/or mitral or tricuspid valve repair of replacement.

All patients suffering from AADA and patients with an extension of ascending aortic aneurysm into the aortic arch underwent surgery under DHCA.

Intraoperative data are displayed in Table 1.

In the reported observation period several cerebral protection techniques have been applied. At the beginning of the observation period patients were cooled, target temperature being 18 °C measured in the tympanum. DHCA was initialized after administration of 20 mg/kg Pentobarbital 2–3 min prior to the arrest. Topical cooling was applied, by covering the head with an ice package. Then, selective antegrade perfusion was introduced in the year 2001. Since then it is used routinely; first by placing catheters in the common trunk and the left carotid artery and then by cannulation of the right axillary artery. With cannulation of the right axillary artery antegrade cerebral perfusion is unilateral. The temperature of the perfusate for ACP is set at 12 °C. ACP during DHCA is performed with oxygenated blood at a pressure of 30–40 mmHg corresponding to a flow of 200–250 ml/min, if the right axillary artery is cannulated ACP is initiated with a flow of 1000 ml/min. Initially cerebral perfusion was mainly applied in patients with an expected arrest of more than 20 min. With the introduction of axillary cannulation in 2003 we started to use ACP in all patients in need for DHCA. During the study period cooling regimen remained the same, we did not combine ACP with moderate hypothermia.

Table 1
Patients from group 1 ($n = 318$) who underwent surgery between January 1996 and December 2000 and patients from group 2 ($n = 517$) who underwent surgery between January 2001 and December 2005

	Group 1 (January 1996 to December 2000)		Group 2 (January 2001 to December 2005)		
Number of patients	318		517		
Mean age (year)	59.4 ± 12.0		61.0 ± 13.0		$p = 0.27$
Male	232	73.0%	379	73.3%	$p = 0.48$
Preoperative data					
CAD	63	19.8%	146	28.1%	$p = 0.004$
Aortic stenosis	51	16.0%	134	25.8%	$p = 0.001$
Ejection fraction <50%	35	15.9%	105	21.0%	$p = 0.06$
Emergency	105	33.0%	160	30.8%	$p = 0.27$
Hemodynamic instability	31	9.7%	63	12.1%	$p = 0.17$
AADA	89	28.0%	152	29.2%	$p = 0.38$
Perioperative data					
Aortic valve replacement	71	22.3%	190	36.5%	$p = 0.00$
Composite graft	106	33.3%	222	39.1%	$p = 0.004$
Ascending aorta replacement	147	46.2%	294	56.5%	$p = 0.002$
Concomitant procedures					
CABG-surgery	52	16.4%	142	27.3%	$p = 0.00$
Others	9	2.8%	24	4.6%	$p = 0.13$
CPB-time (min)	119 ± 21		130 ± 27		$p = 0.01$
ACC-time (min)	75 ± 15		84 ± 14		$p = 0.00$
DHCA-time (min)	19 ± 7		22 ± 6		$p = 0.54$
Aortic cannulation	113	35.5%	294	56.5%	$p = 0.00$
Femoral cannulation	201	63.8%	113	25.1%	$p = 0.00$
Axillary cannulation	1	0.3%	114	21.9%	$p = 0.00$
Surgery with DHCA	194	61.0%	301	57.0%	$p = 0.206$
DHCA and ACP	0	0.0%	196	65.1%	$p = 0.00$

Results are displayed as average values (±1 SD) or absolute values. CAD, coronary artery disease; AADA, acute aortic dissection type A; CABG-surgery, coronary artery bypass surgery; CPB-time, cardiopulmonary bypass time; ACC-time, aortic cross-clamping time; DHCA-time, deep hypothermic circulatory arrest time; ACP, antegrade cerebral perfusion.

2.2. Statistical analysis

Data are presented as mean values ± their first standard deviation. A Mann–Whitney *U*-test and χ^2 test were used for comparison between groups of continuous and nominal variables, respectively.

A *p* value of less than 0.05 was considered significant. A logistic regression analysis was done.

3. Results

Patients' characteristics are displayed in Table 1.

Adverse outcome (AO), defined as in-hospital death or permanent neurological deficit, occurred in 101 of 835 patients (12.1%). Initially, all patients were treated as a single group, but subsequently, to study the impact of the different time period of surgery, patients were divided into an early and a late group according to the year they underwent surgery. Group 1 includes 318 patients (38.2%) who underwent surgery on the thoracic aorta between January 1996 and December 2000. During this period the main protection strategy during circulatory arrest was the profound cooling. Group 2 consists of 517 patients (61.8%) being operated between January 2001 and December 2005. In this study period ACP was used routinely in most cases with expected long duration of circulatory arrest.

Demographics and intraoperative data of these groups are displayed in Table 1.

In the last 10 years there was a pronounced increase in aortic caseload. This increase was seen in patients operated for TAA (+367.9%) as well in patients for AADA (+276.9%).

The demographics of group 1 compared with group 2 looking at age (59.4 ± 12.0 years vs 61.0 ± 13.0 years; $p = 0.27$), sex (male 73.0% vs 73.3%; $p = 0.48$) and cardiovascular risk profile revealed no significant difference during the last decade. A similar amount of surgery had to be performed in emergency (group 1: 33.0% vs group 2: 30.8%; $p = 0.27$). In group 1 89 patients (28.0%) had to be operated because of AADA, in group 2 152 patients (29.2%) ($p = 0.38$).

Significantly more patients were found in group 2 with comorbidities known to influence outcome in cardiac surgical procedures, according to the EuroSCORE: concomitant coronary artery disease (group 1: 19.8% vs group 2: 28.1%; $p = 0.004$) and impaired left ventricular function with an ejection fraction (EF) <50% (group 1: 15.9% vs group 2: 21.0%; $p = 0.07$). In group 2 more patients suffered from aortic valve stenosis (group 1: 16.0% vs group 2: 25.8%; $p = 0.001$) and mitral-valve insufficiency (group 1: 8.2% vs group 2: 10.3%; p = ns).

The number of Bentall-procedures increased from 33.3% in the early study period up to 42.7% in recent years ($p = 0.004$), reflecting the attempt to treat the aortic root more radically. This explains the increase of combined procedures in recent years: additional CABG-surgery (group 1: 16.4% vs group 2 27.3%; $p = 0.00$) and repair/replacement of the mitral- and/or the tricuspid-valve (group 1: 2.8% vs group 2: 4.6%; $p = 0.133$).

There was no difference in the percentage frequency of DHCA: in the early group 194 patients (61.0%) had DHCA compared to 301 patients (57.0%) in the late group ($p = 0.206$). In the early group DHCA was performed without additional ACP. In 2001 ACP was introduced in clinical routine: in group 2 196 patients (65.1%) had ACP. In the whole study period 299 patients were operated with DHCA alone. ACP had a positive effect on mortality (7.7% vs 10.3%) as well as on persistent neurological dysfunction (6.3% vs 8.2%).

The cannulation technique changed as well: femoral cannulation (group 1: 63.8% vs group 2: 25.1%; $p = 0.00$) being abandoned for the axillary cannulation (group 1: 0.3% vs group 2: 21.9%; $p = 0.00$).

Mean cardiopulmonary bypass (CPB) time was similar in both groups (119.3 ± 20.9 min vs 130.1 ± 16.9 min; $p = 0.014$), as was the mean duration of DHCA (19.2 ± 7.1 min vs 22.0 ± 8.9 min; $p = 0.054$).

Intraoperative mortality remained the same, four patients (1.3%) died during the operation in group 1, eight patients (1.5%) in group 2. In-hospital mortality decreased: 25 patients (7.9%) died in the early group and 29 patients (5.6%) died in the recent group (Fig. 1). The decrease in mortality more pronounced in patients undergoing surgery for AADA, than in surgery for TAA (Fig. 2).

Thirty-three patients (10.4%) suffered from permanent neurological dysfunction in group 1, compared to a decrease to 14 patients (2.7%) in group 2 (Fig. 3) ($p = 0.00$). Also in this aspect the decrease is more pronounced in AADA (Fig. 4). Overall AO, as defined above, has dramatically decreased from 58 patients (18.2%) to 43 patients (8.3%) in the later period of the study.

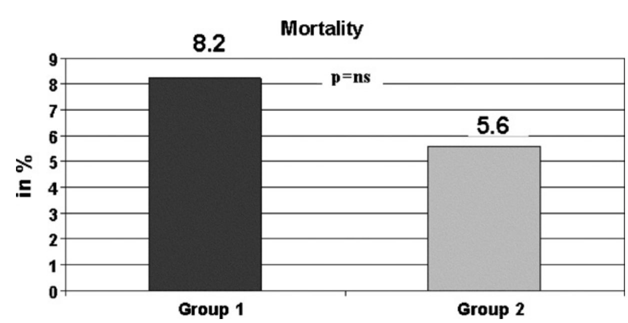

Fig. 1. In-hospital mortality in patients from group 1 ($n = 318$) and group 2 ($n = 517$).

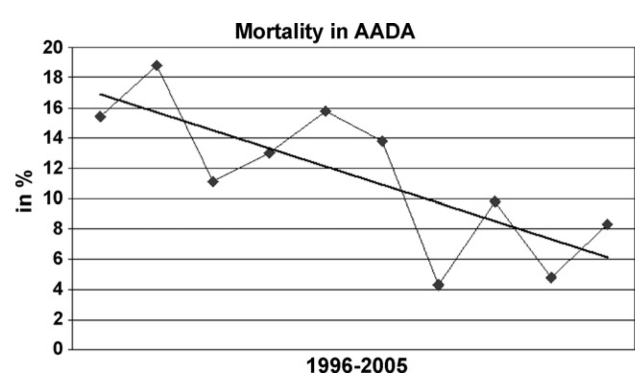

Fig. 2. Mortality in AADA between 1996 and 2005 in percentage. Logistic regression curve is displayed.

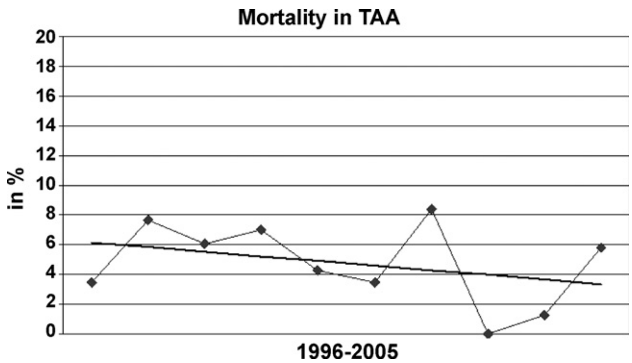

Fig. 3. Mortality in TAA between 1996 and 2005 in percentage. Logistic regression curve is displayed.

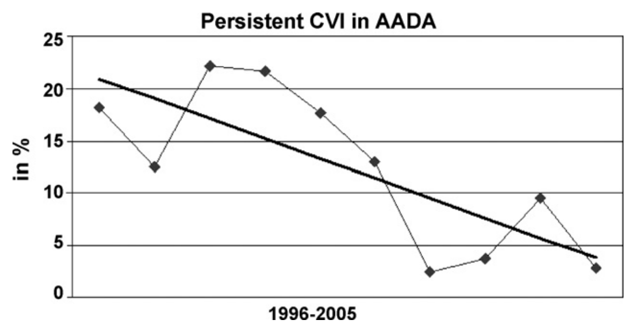

Fig. 4. Persistent cerebrovascular incidents in AADA between 1996 and 2005 in percentage. Logistic regression curve is displayed.

4. Discussion

The pronounced increase in aortic caseload is mainly due to the larger availability of CT-scans. There are more patients identified with asymptomatic TAA. From several previous studies, which have consistently shown that emergent operations on the thoracic aorta, due to aortic dissection, are associated with an increase in adverse outcome [11], we tend to be more aggressive in treating patients in an elective manner and in an earlier stage of the disease. The increase in patients with AADA is probably also related to earlier diagnosis based on the availability of CT-scans and echocardiography, allowing fast reference to a specialized heart surgery unit, which improves outcome in these patients (Fig. 5).

Technical improvements and better surgical results, despite an increase in the incidence of comorbidities and the amount of combined procedures, allow us to extend the indications and to operate on patients, who would not have been considered for elective surgery a few years ago.

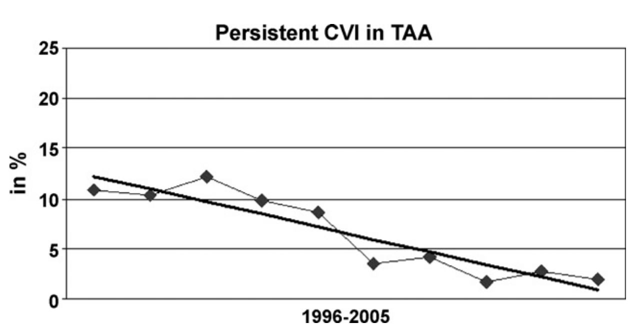

Fig. 5. Persistent cerebrovascular incidents in TAA between 1996 and 2005 in percentage. Logistic regression curve is displayed.

In the light of sicker patients and more complex surgery the dramatic decrease in mortality and permanent neurological dysfunction is even more remarkable. In accordance with other groups, we are able to show a pronounced decrease in permanent neurological deficits [6]. Postoperative permanent neurological deficits after surgery on the thoracic aorta and aortic arch usually result from cerebral emboli during surgery. Thus the avoidance of any manipulation of the diseased aorta is probably one of the major advances in thoracic aortic surgery in the last decade. In the earlier years of this study the main method to protect the brain during circulatory arrest was to decrease the metabolic demand by cooling the patient to 18 °C. Several studies have shown, that with this approach the safe duration of arrest is limited [8—11]. Therefore the search for refined method of protecting the brain resulted in groups favoring the use of retrograde cerebral perfusion [12,15,16] reporting very good results. The advantage of RCP being more thorough cooling of the brain and washing out air and debris material from the intracranial vessels. Other groups reported conflicting results using RCP and the benefit remains unclear [12—17]. Although several groups were able to show a benefit from RCP, we and others are rather sceptical whether there is a benefit other than just more thorough cooling of the brain with the risk of developing cerebral edema [16,17]. Some reports have documented that prolonged RCP is a risk factor for stroke and mortality, such as being observed in prolonged DHCA. In our clinical routine we did not use retrograde cerebral perfusion.

Bachet and co-workers introduced the concept of antegrade cerebral perfusion in combination with moderate hypothermia [9]. The introduction of axillary artery cannulation in clinical routine [18,19] allows removing the balloon-catheters from the surgical field and reduces manipulation on the supra-aortic branches, favoring air and thrombotic embolisms. In recent years, we tried to avoid cross-clamping the aorta, especially in AADA as well as in aorta with severe atherosclerotic alterations.

Another great advance in using ACP in combination with axillary cannulation is the preservation of antegrade flow in the descending aorta while eliminating some of the risks associated with direct cannulation of the ascending aorta [6,7]. Axillary cannulation is also superior to femoral cannulation, which reverses blood flow in the descending aorta and may shear off embolic material and can thus cause dissection or embolic showers [18,19]. The axillary artery has less atherosclerotic alterations than either the ascending aorta or the femoral artery. Axillary cannulation lowers the potential risk of embolization into the right sided cerebral vessels by perfusing them with flow which has not transversed the aortic arch and avoids the sandblast effect of turbulent flow from a catheter tip close to atherosclerotic lesions in the ascending aorta and thus reduces the risk of embolization into the left-sided cerebral vessels.

The observed increase in CPB-time in recent years is partly related to this technique and especially to the increase of combined procedures. Outcome data confirm that this slight increase of CPB-time does not adversely affect the overall benefit. Beside the reduction of neurological events, our group has recently shown that the use of selective ACP during DHCA improves quality of life after interventions on the thoracic aorta [5].

The use of glue in surgery for AADA has the advantage of closing the entry of the dissection but increases the risk of necrosis of the arterial wall [20,21]. We perform regular clinical follow-up in all our patients who underwent surgery of the thoracic aorta, including an imaging study such as an angio-CT or MRI. In this large collective of patients we have not seen any formation of aneurysm due to the use of glue.

We therefore conclude, that technical advances in the field of thoracic aortic surgery lead to a decrease of mortality and morbidity. With our results in this large collective of patients we were able to show a dramatic decrease especially in the incidence of adverse neurological events over the last decade. This is mainly due to better surgical techniques, such as antegrade cerebral perfusion and a no-touch policy on the ascending aorta. Even though our patients become sicker and operations are getting more complex with more concomitant procedures, the outcome after surgery on the thoracic aorta significantly increases with a better long-term quality of life.

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